Design improvements in the electromagnetic pumps used in sodium systems of Indian FBRs

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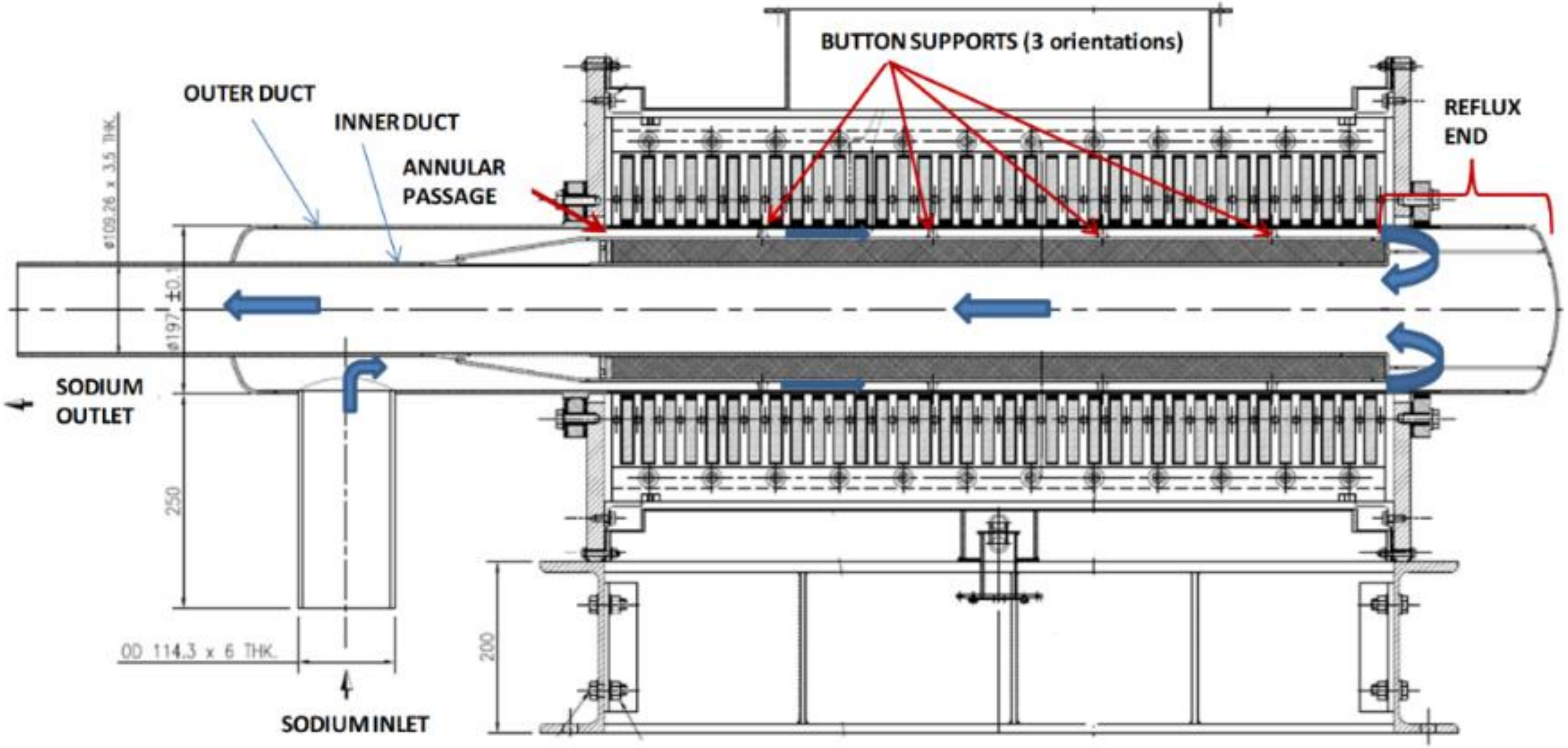
Schematic arrangement of Reflux type EM Pump



Duct material: SS304LN

Flow rate: 170 m^3/h

Head developed: 4 bar

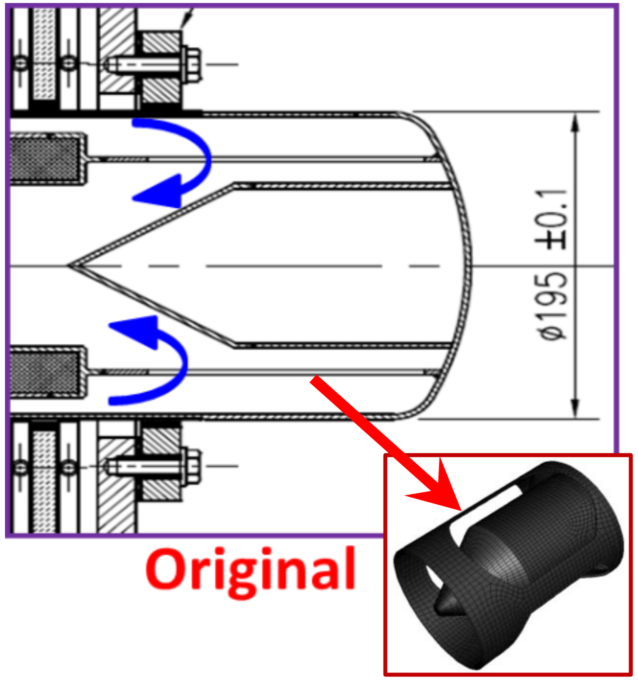
Power: 98 kW

Na Temp.: 400 °C

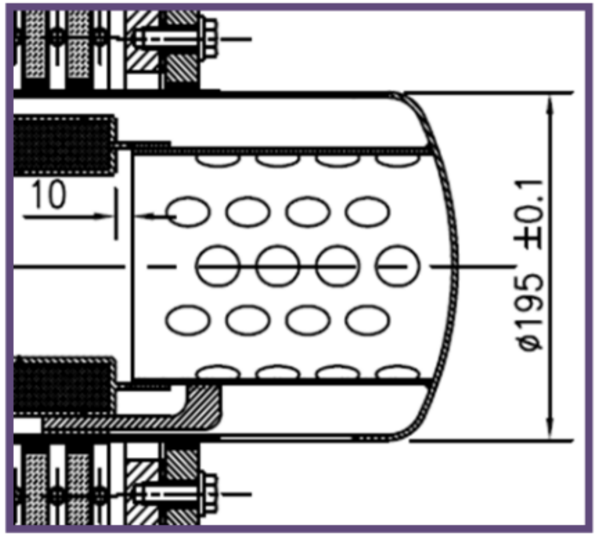
Winding Temp: 180 °C

- Pumping: Lorentz force generated in sodium by Interaction of travelling magnetic field & induced current.
- Why reflux type? Winding coil is removable without cutting sodium duct assembly.
- Used for large sodium flow rates (> 50 m^3/h)

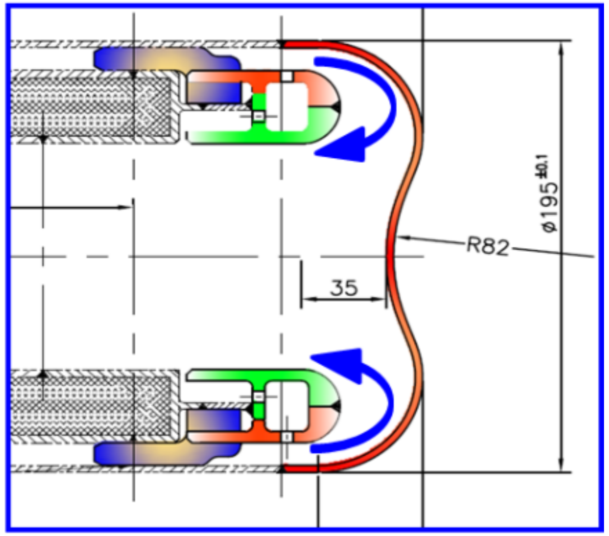
Initial and modified designs of Reflux end duct assembly



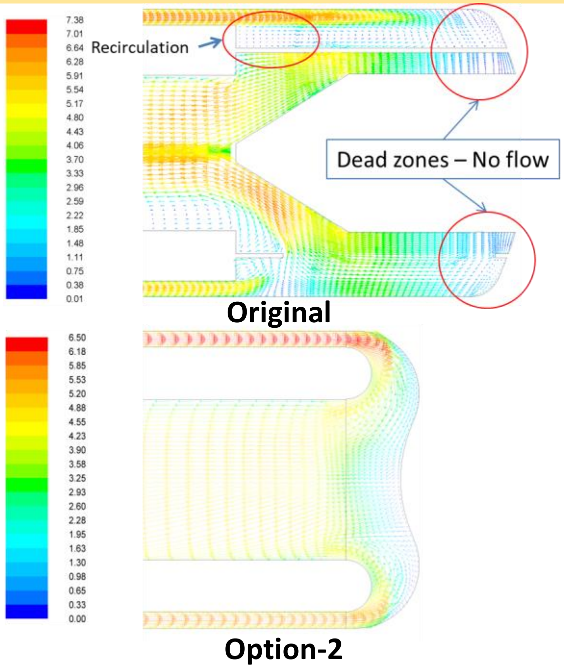
Original



Option-1



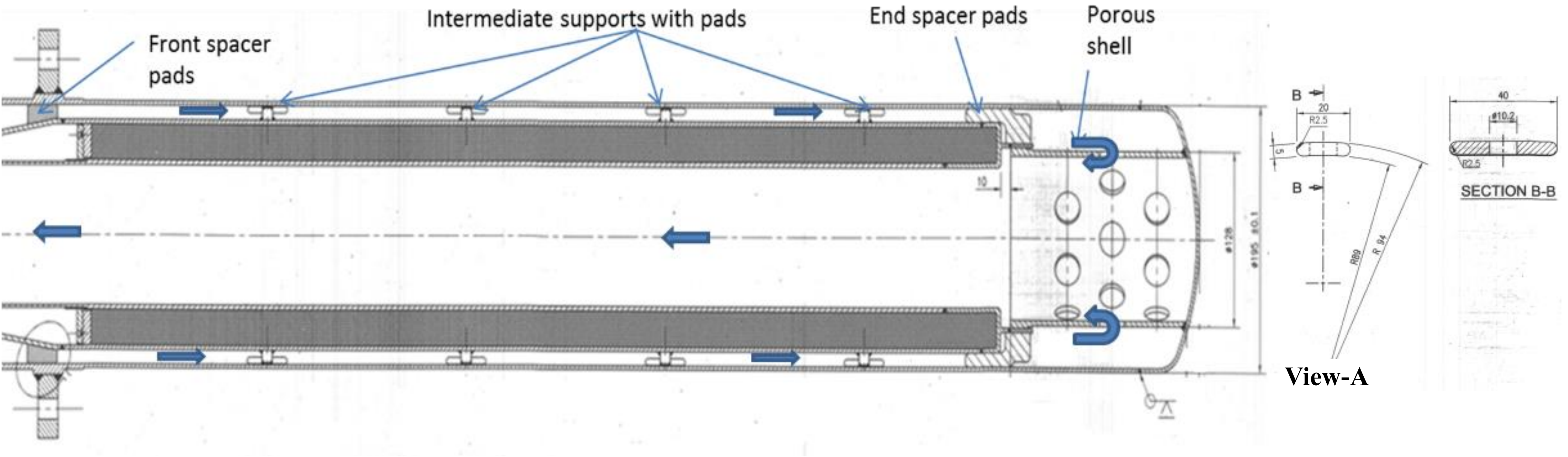
Option-2



Affects joint life

- Initial design: Either end of inner duct (thick core) is welded with outer duct.
- Sodium draining transients: Diff. temperature induces thermal fatigue at ribs.
- **Option-1:** Sliding joint proposed with hardfaced end pads to allow diff. expansion (upto 10 mm). Porous shell for distributed turning flow.
- **Option-2:** Complete disconnection of inner duct except guide pads, configuration of smooth turning profile arrived using CFD (elimitate stagnant zone) are proposed for future FBRs.

Modified sodium duct assembly with additional pads



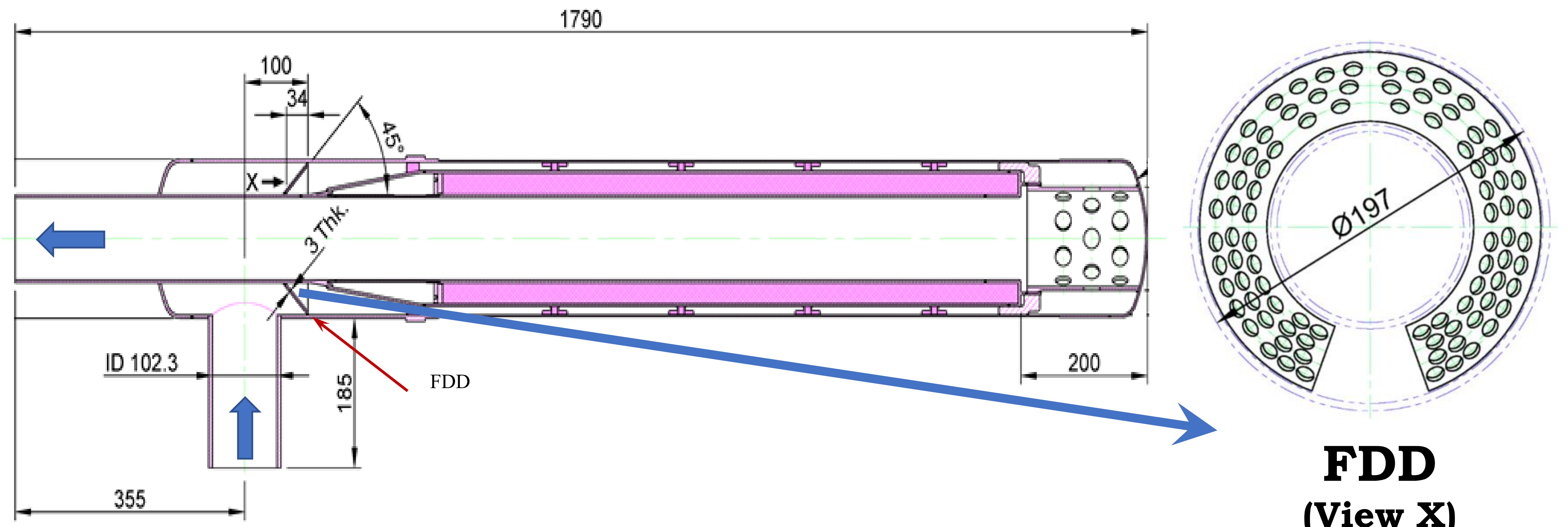
- To minimize duct’s lateral vibration from 3 mm/s end pads with colmonoy-5 coating on mating surface (to avoid self welding) is proposed. This minimised vibration to below 1.5 mm/s. However, acceptable limit is 5 mm/s.
- Intermediate spacer buttons also added with wider pads to minimize fretting wear.

Flow distribution to annulus entry: Importance

- Turning flow due to radial entry to the annular duct leads to non uniform velocity.
- Any flow mal-distribution at entry to annular duct: leads to onset of magneto hydrodynamic instability [1]. This is to be avoided for all pump operation range.
- Can be achieved by either large resistance porous plate which offers large suction drop affecting NPSH of pump
- Alternate option: Non uniform porous plate arrived using iterative CFD analysis.

Ref [1]: Takatoshi Asada, Yosuke Hirata, Rie Aizawa, Yasushi Fujishima, Tetsu Suzuki & Eiji Hoashi (2015) Development of a three-dimensional magnetohydrodynamics code for electromagnetic pumps, Journal of Nuclear Science and Technology, 52:5, 633-640, DOI: 10.1080/00223131.2014.961988

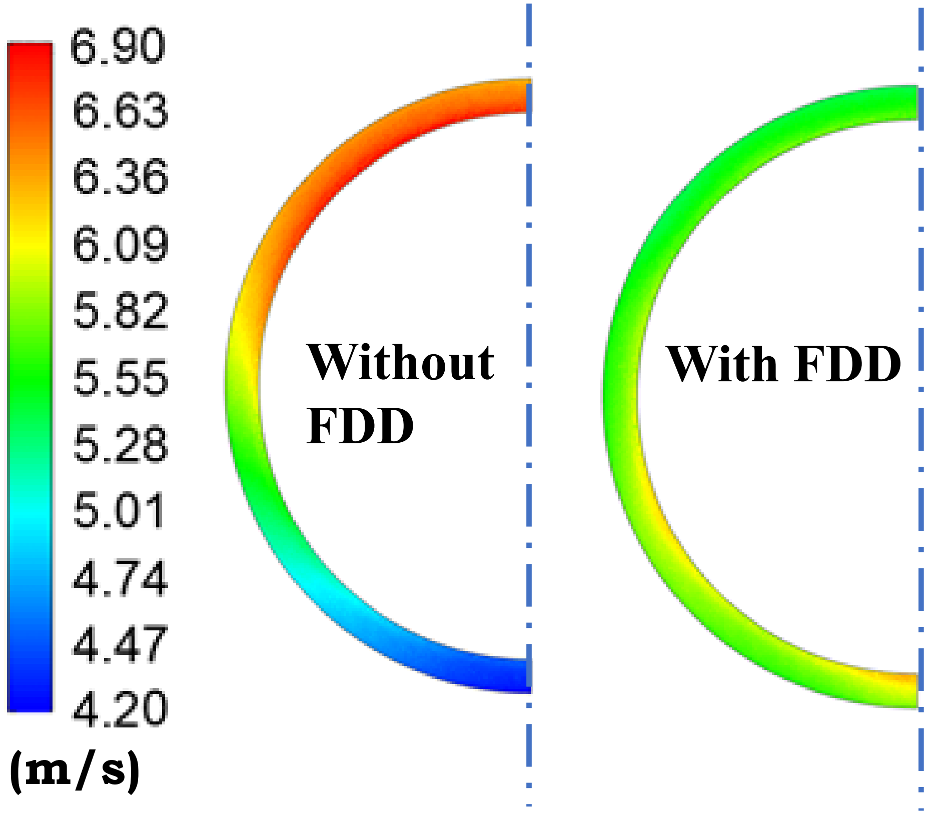
ALIP with Flow Distribution Device (FDD) at entry to annular path



FDD
(View X)

- Frustum of cone is chosen to meet minimum hole size needed in sodium flow path respecting porosity requirement.
- Final non-uniform porosity: Arrived using iterative CFD studies.

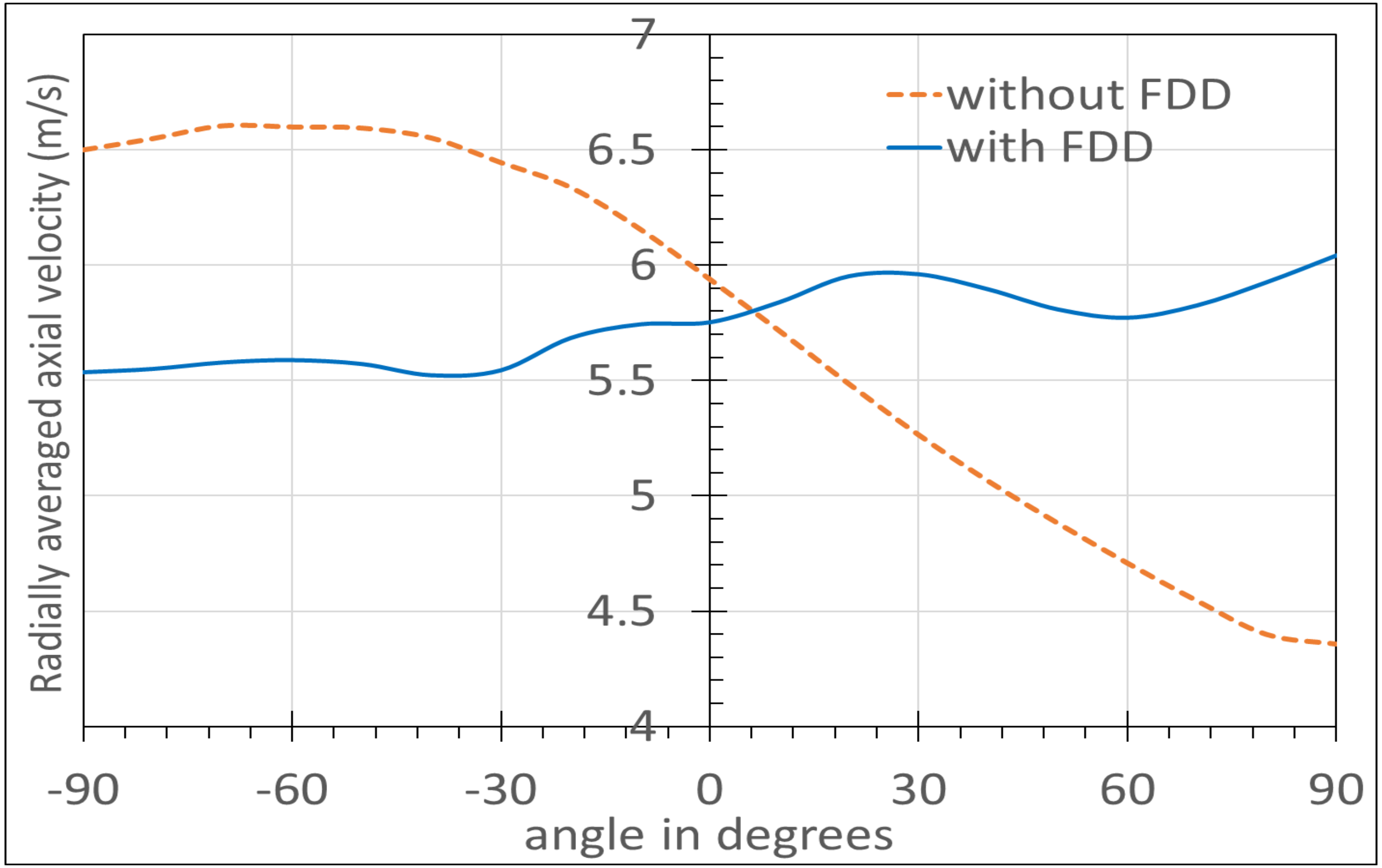
Axial velocities at entry to annular portion without (left) and with (right) FDD



Axial velocities at entry to annular portion

- With final FDD: circumferential variation of radial averaged velocity reduced from 2.4 m/s to 0.3 m/s.
- With the device, overall pressure drop increases by 8 kPa which is insignificant considering developed head of 400 kPa.

Circumferential variation of axial velocity at entry to annular portion for 120 m³/h



Standard deviation (about V_{mean}) of radially averaged velocities at inlet to annulus, reduces significantly from 0.84 m/s without FDD to 0.17 m/s with the device for flow rate of 120 m^3/h

Summary

- Reflux type EM Pumps are deployed across multiple sodium loops within Indian FBRs.
- Drawing from operating experiences, several design improvements are carried out for refining the performance and availability of these EM Pumps.
- The improved design features have undergone testing in both water and sodium loops and found to be effective.
- These improvements have since been integrated into various sodium loops of FBRs and performing satisfactorily.

Thank You…

References

[1] Nashine, B.K., Rao, B.P.C., Design, In-sodium Testing and Performance Evaluation of Annular Linear Induction Pump for a Sodium Cooled Fast Reactor, Ann. Nuc. Energy 73 (2014) 527-536, https://doi.org/10.1016/j.anucene.2014.07.026

[2] Sharma, P., Mani, A., Nashine, B.K., Performance Evaluation of a Continuous and a Discontinuous Magnetic Circuit Annular Linear Induction Pump, Ann. Nuc. Energy 158 (2021) 108241, https://doi.org/10.1016/j.anucene.2021.108241

[3] Ram Kumar Maity, R. Nandakumar, Juby Abraham, K. Natesan, N. Kasinathan, K. Velusamy, Optimisation of Reflux Head of an Electromagnetic Pump, Proceedings of the 7th Intl. and 45th National Conference on Fluid Mechanics and Fluid Power, December 10-12, 2018, IIT Bombay.

[4] Araseki, H., Kirillov, I.R., Preslitsky, G.V., Ogorodnikov, A.P., Magneto Hydrodynamic Instability in Annular Linear Induction Pump, Part-I. Experiment and Numerical Analysis, Nuc. Eng. Des. 227 (2004) 29-50, https://doi.org/10.1016/j.nucengdes.2003.07.001.